Elastic Scattering with MINERνA

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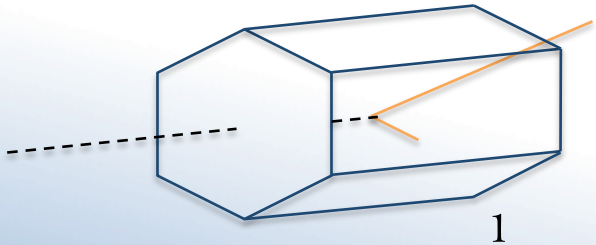
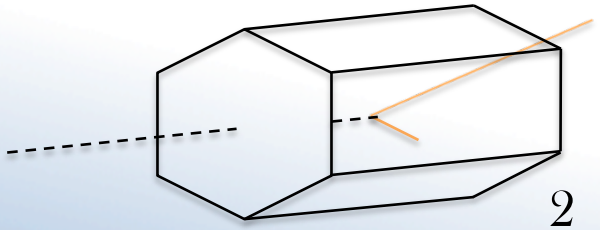


Brief Outline

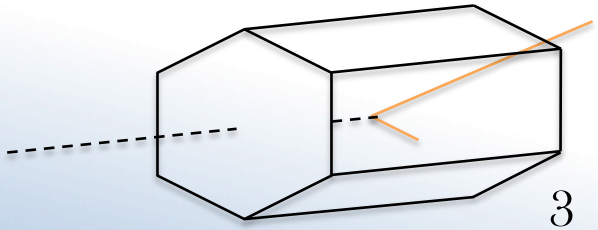
- Quick survey of neutrino elastic scattering
- MINERνA: detector, data sets, rates, elastic scattering
- Recent results from MINERνA
- Steps towards more comprehensive elastic scattering results
- Conclusions and Acknowledgements



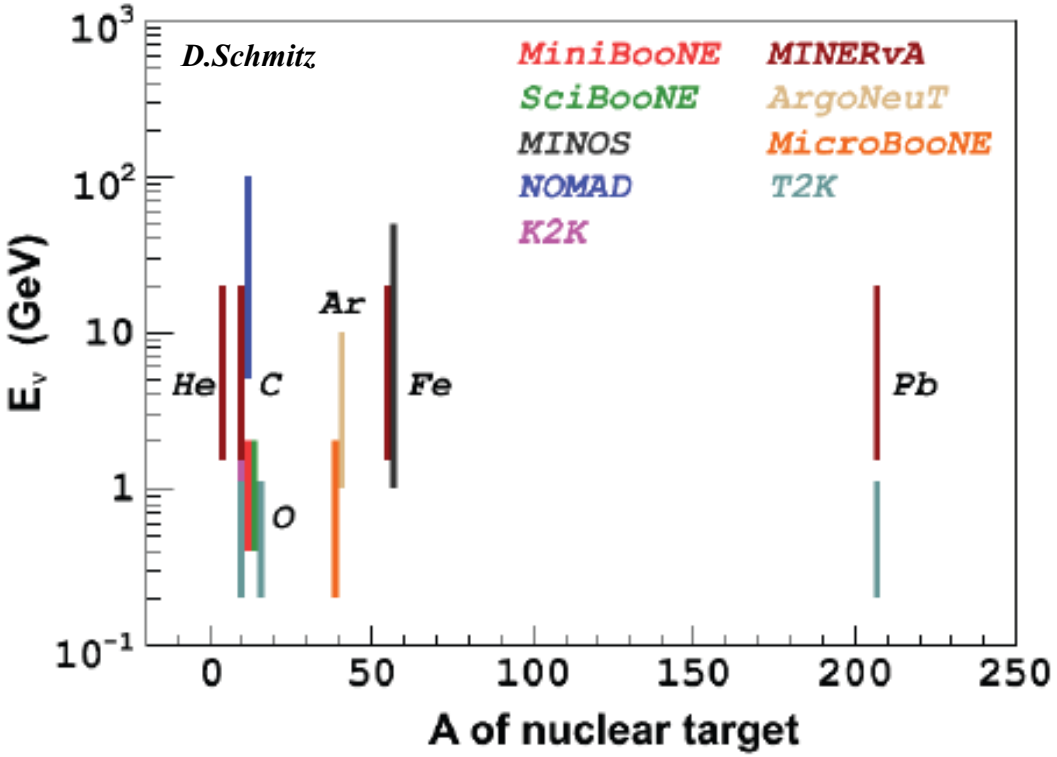
Neutrino Elastic Scattering

- Elastic scattering is the signal used in many oscillation experiments; the precision of oscillation parameter extraction is directly related to the precision of the input parameters.

- Cross sections for both neutrinos and anti-neutrinos have a wide range of values in energy ranges of current oscillation experiments. In addition, there is a range of target mass used in these experiments.

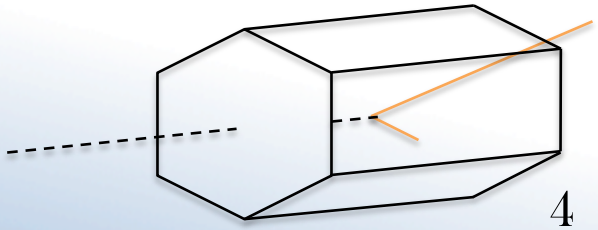


Experimental Situation



E_ν: 0.1-100 GeV/c
A: 4-207 amu

✌ Different neutrino experiments use different neutrino energy and target mass. Two orders of magnitude are spanned for each variable with the shown experiments.

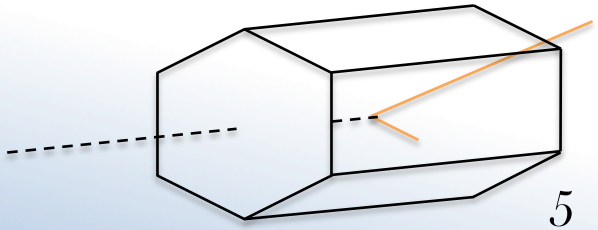


Elastic Scattering Theory

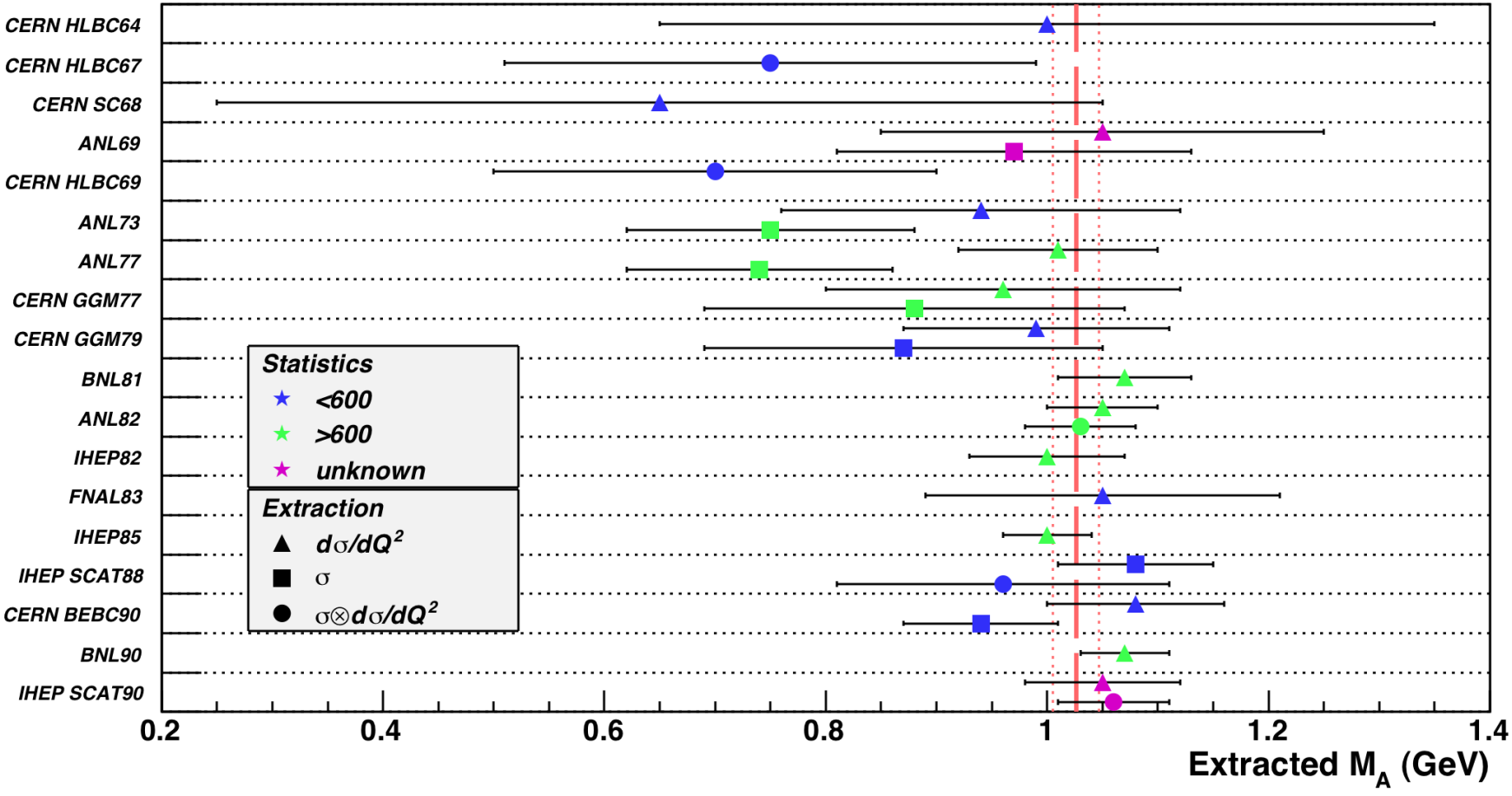
- The cross section has a total of six form factors that can be constructed from the available hadronic four momenta.

- Symmetry arguments reduces the number of unknown form factors and certain parameterizations are used for the others.
  - pseudoscalar factor is multiplied by the outgoing lepton mass
  - one axial parameterizations is: $f(Q^2) = a(1 + b^{-1}Q^2)^{-2}$
  - modifications due to meson exchange current, 2p2h, etc.

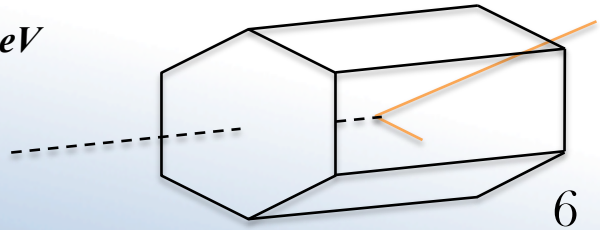
- Thus, elastic scattering (less 2p2h additions) can be described by two parameters: a ($=f_a(0)$) and b ($=M_a^2$). The first is a well-known and is accurate to 0.2%; the second is dubbed the axial mass and extracted from data.



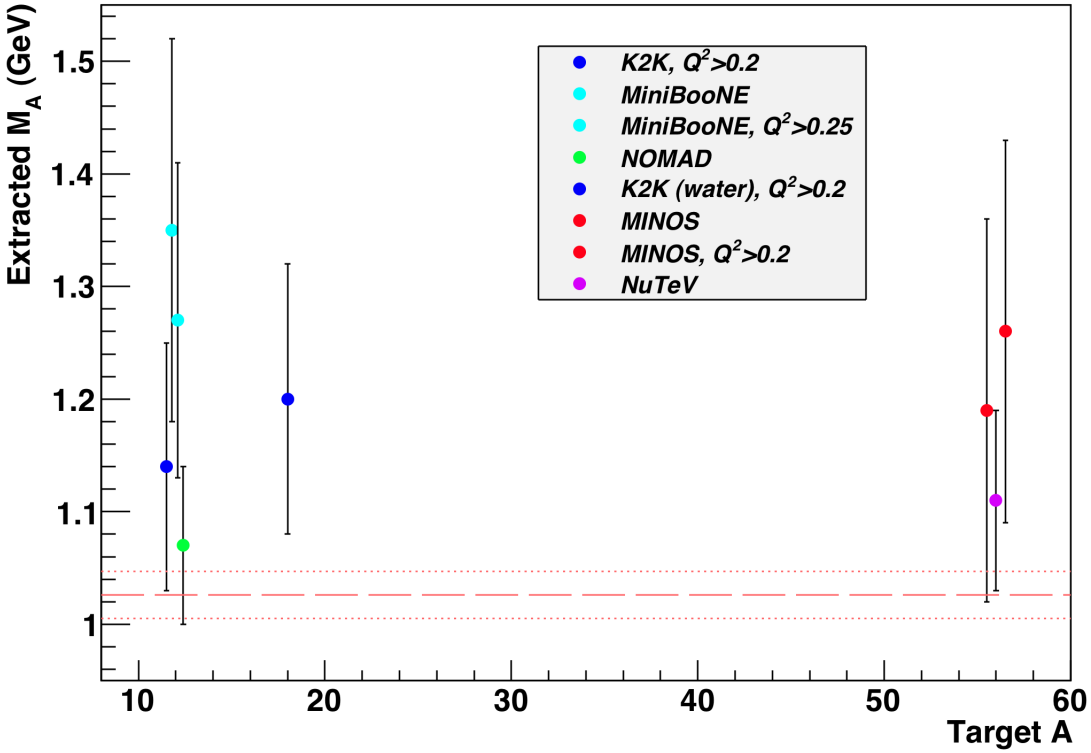
Experimental Axial Mass Values



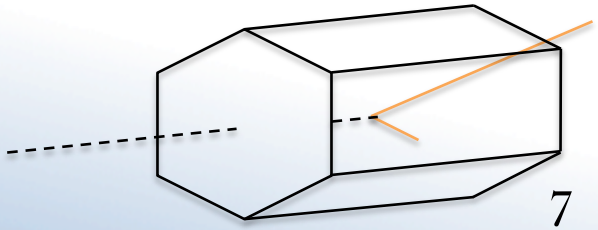
- *experimental picture from 1964-1990*
- *wide range of target used*
- *line represents M_A ~ 1.03 GeV*



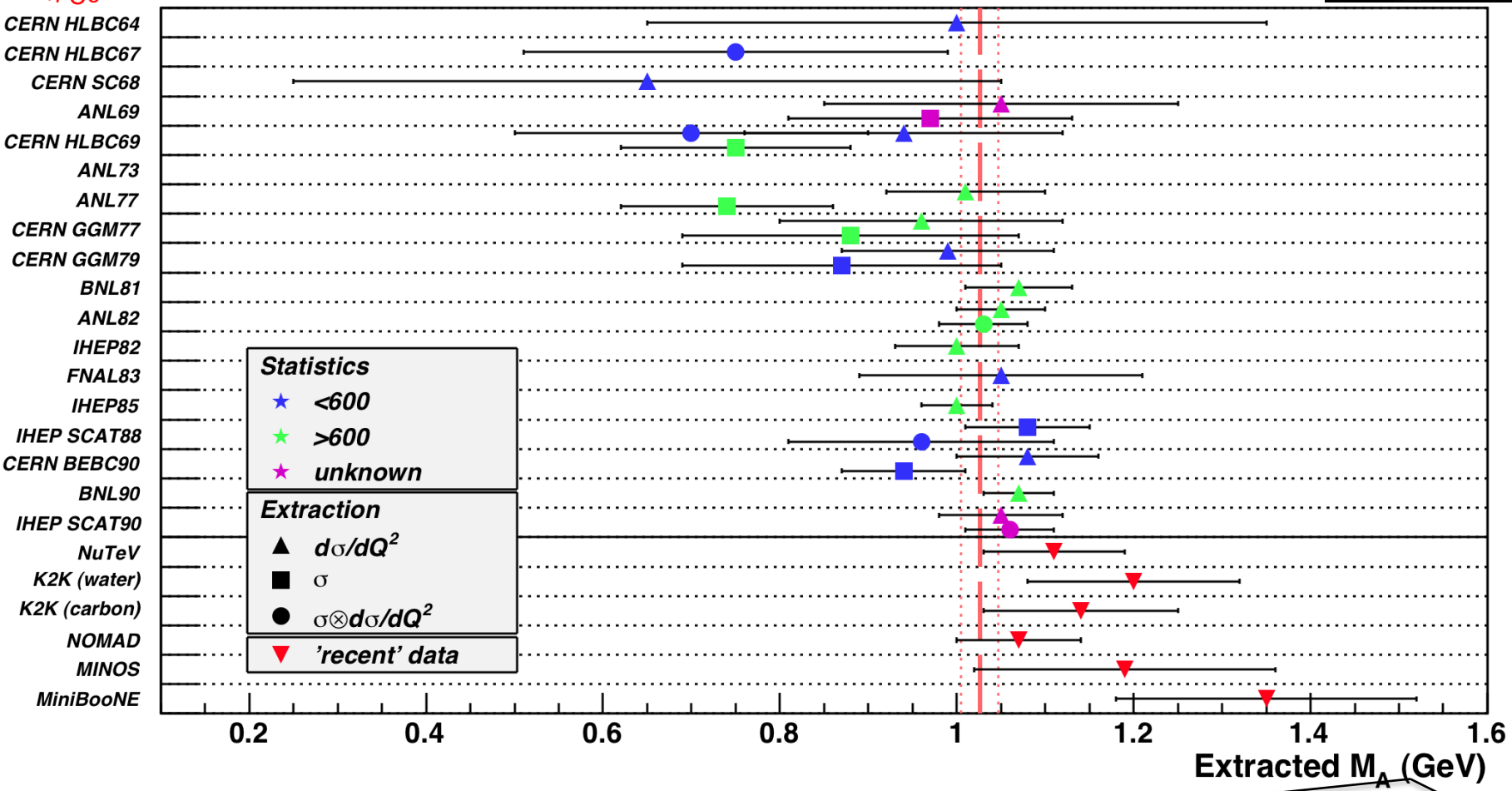
Recent Axial Mass Measurements



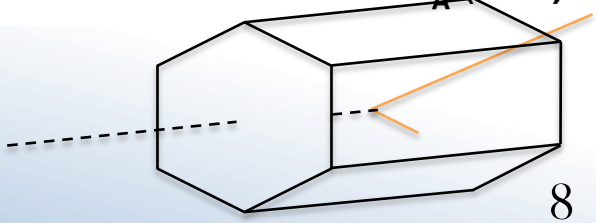
✌ There is stability, but M_A is clearly higher than measured previously. These different experiments had different techniques and technologies.



Conflicting Axial Mass



- *new measurements clearly higher than old…*



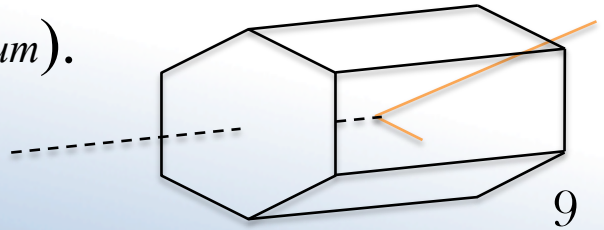
Next Generation Measurements

✌ The next generation of oscillation experiments will need the best input for their analyses. Variations of the axial mass yield different cross sections that, in turn, vary oscillation results.

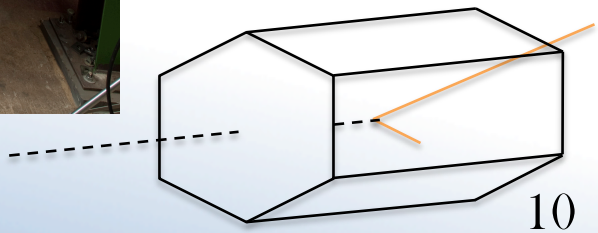
✌ Minerva will be able to collect key information for these next generation experiments.

- variation of interactions due to varying nuclei: J.Devan
- test dipole parameterization (i.e. M_A) for ν and anti-ν
- investigate MEC, 2p2h, etc.

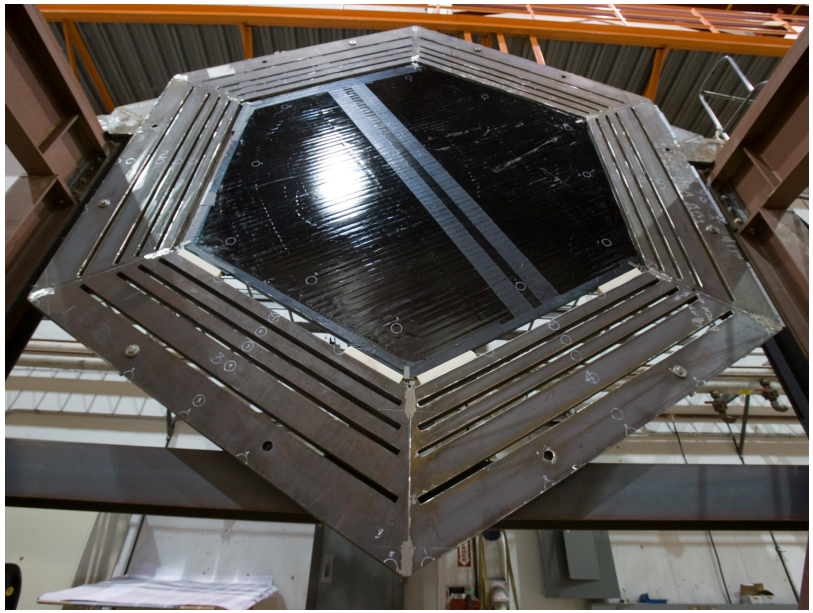
✌ We are creating a new era of data. Precision measurements allow new theories to be tested (and then give experimenters new models to test, and their data can be used to create new theories …*ad infinitum*).



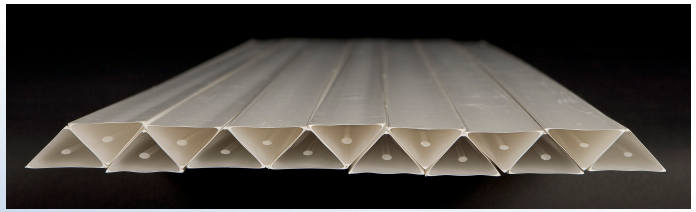

MINERvA

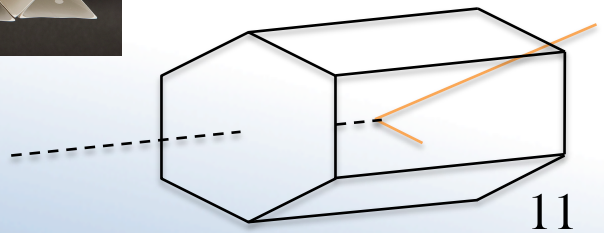


MINERvA



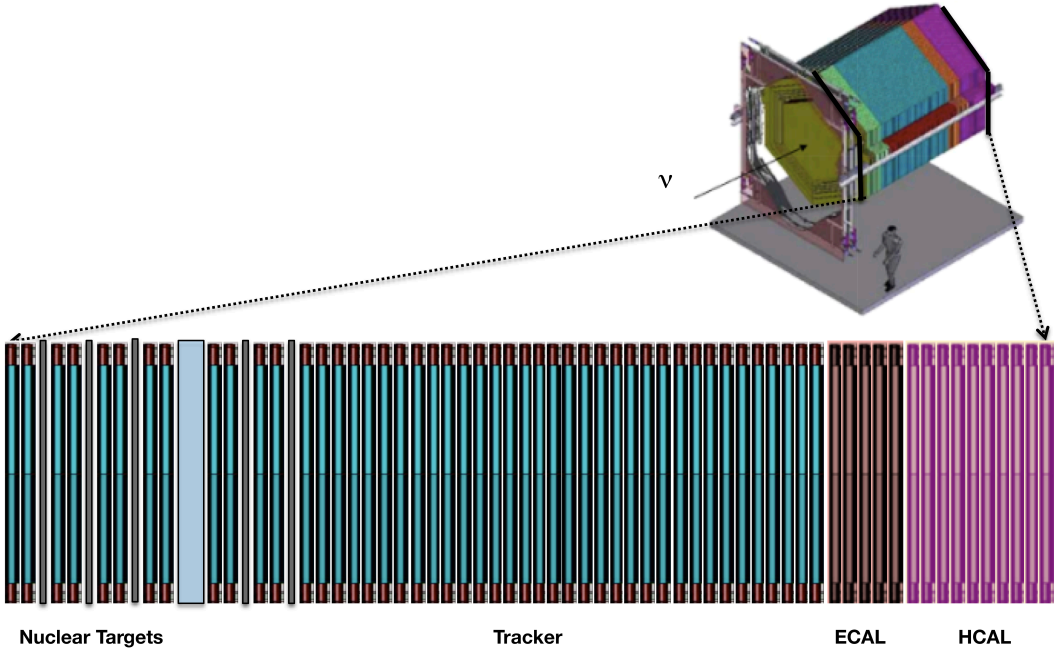
- Fine-grained, modular detector, comprised of repeating plane structure, planes are pure scintillator or fitted with absorber.
- Light is collect via fibers and read out with photo-multiplier tubes.
- Roughly 6.5 ton solid scintillator (CH) fiducial volume in main tracking region.

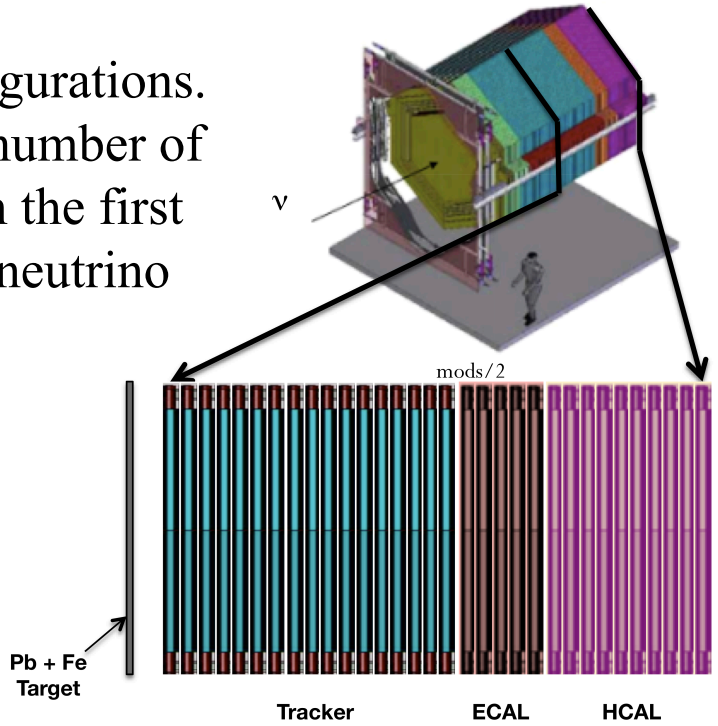


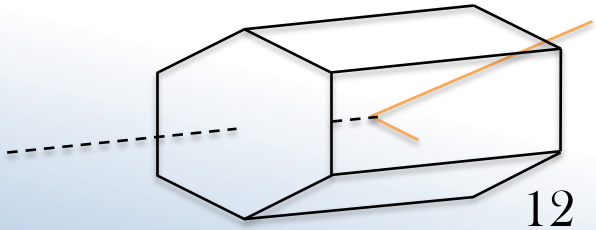


MINERvA

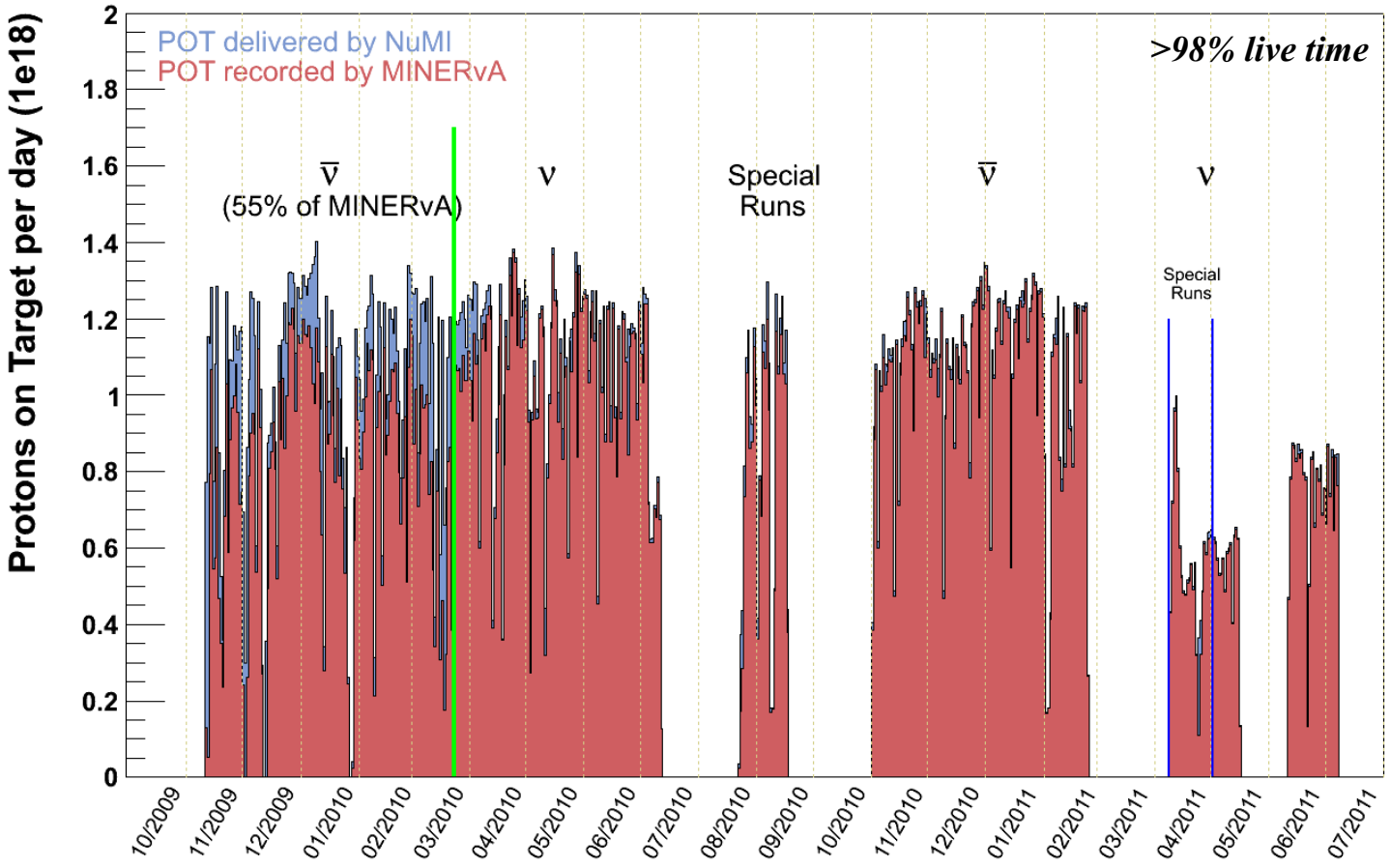
- MINERvA collected data in two distinct configurations. The first configuration had roughly half of the number of tracking modules of the final one. Note, data in the first detector configuration was taken in NuMI anti-neutrino mode.

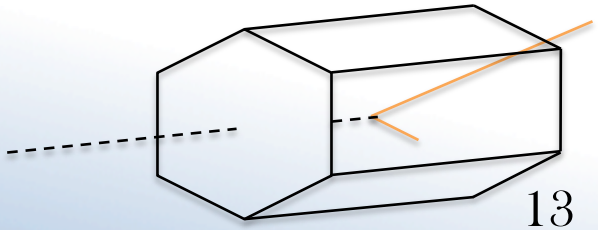






MINERvA POT and Live Time



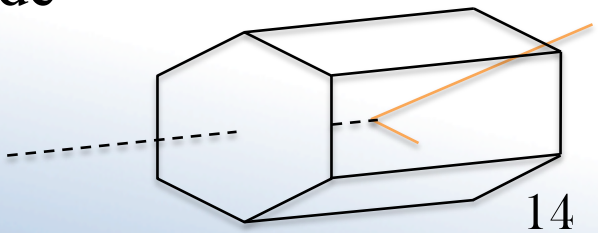


MINERνA CC Event Rates

Detector/POT/beam	Tracker Fiducial Vol.	Elastic Component
partial, 0.8e20, LE anti-ν_μ	44k	15k
full, 1.28e20, LE ν_μ	436k	90k
full, 1.5e20, LE anti-ν_μ	168k	57k
full, 4e20, LE ν_μ	1363k	280k

- Charged current rates obtained with Genie (v2.6.2) assuming 3 and 6.5 ton fiducial volumes for the partial and full detector, respectively

- In the current run plan MINERνA have beam exposures of roughly 4.0e20POT in LE ν and 12e20POT in ME ν mode

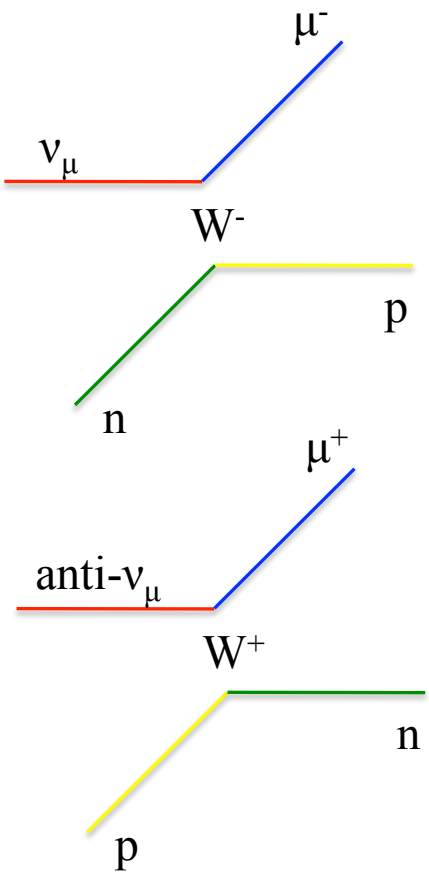


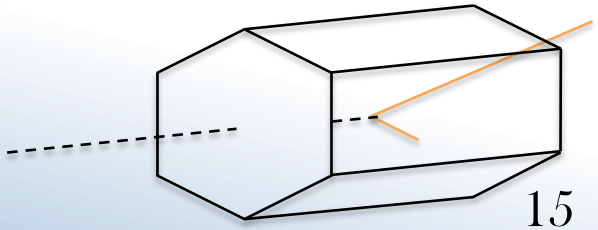
Charged Current Elastic Scattering

- MINERνA data sets in both modes of the NuMI beam will represent a large increase in the current world elastic sets.

- Elastic scattering signatures are either single, penetrating track, or the same with stray energy deposition possibly vertexed with other track.
  - MINOS graciously provides muon information
  - hadron analysis depends on data set

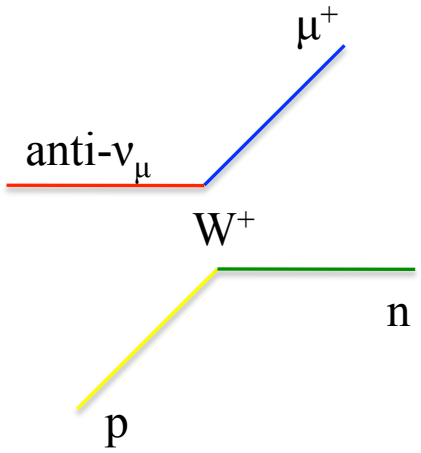
- We have a responsibility to provide input to our neutrino colleagues: theory and experimental.





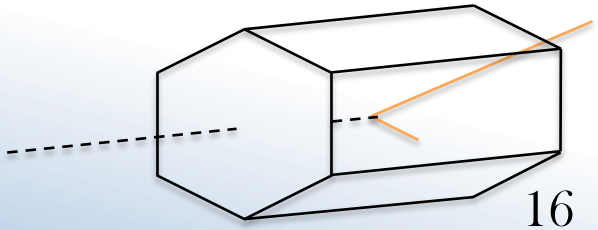
Anti-Neutrino Elastic Scattering

- The first analysis of elastic scattering is being done with the partial detector data set. This will serve as the foundation to all further elastic studies.



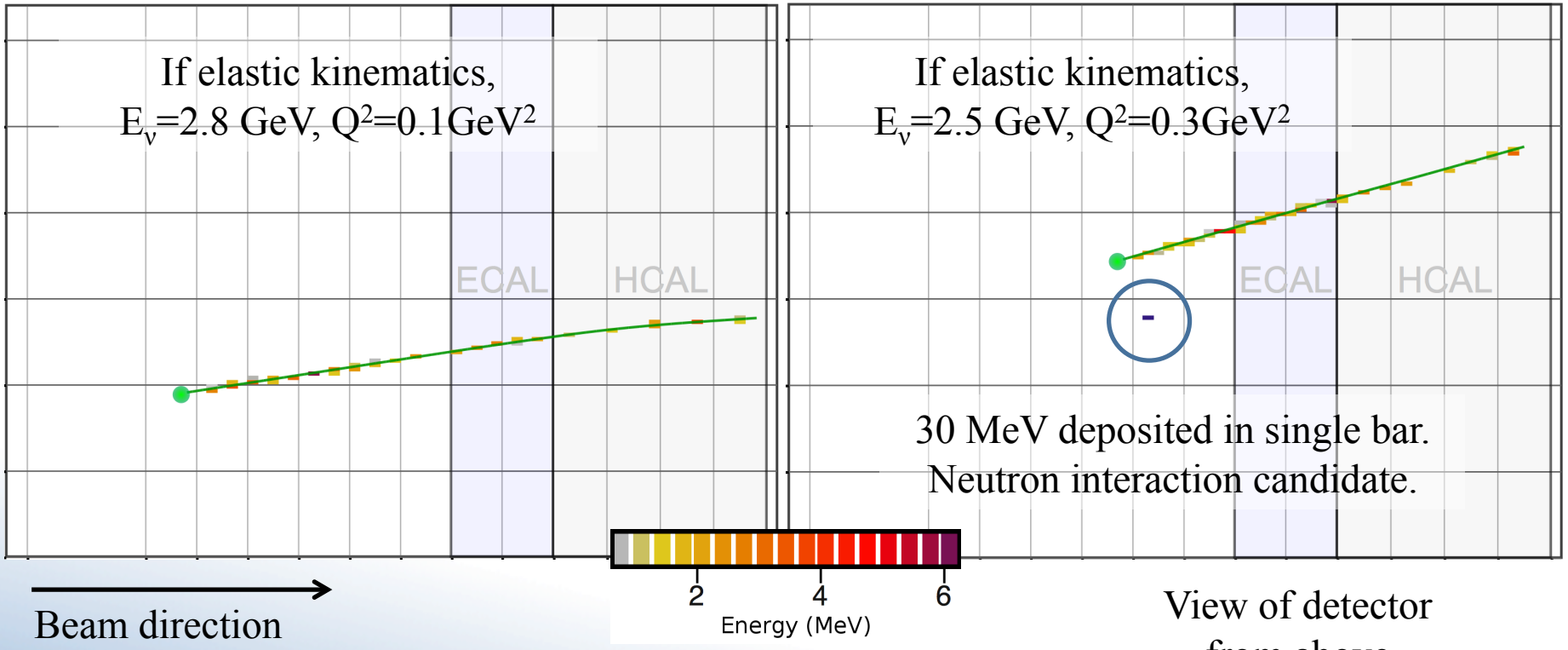
- Current anti-neutrino event selection:
  - one track in FV (~3 tons)
  - momentum analyzed MINOS matched track
  - Q^2 dependent recoil cut for QE enhancement

- This analysis is on-going project; what is being shown is the ***state of the analysis at NuINT11 (March 2011)***.

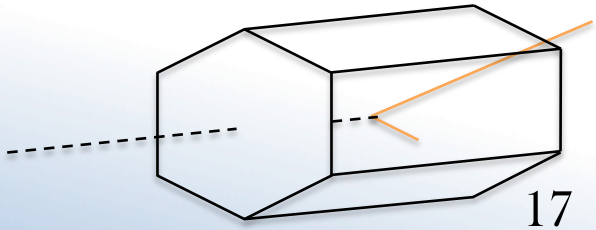


Sample Event Displays

anti-$\nu_\mu p \rightarrow \mu^+ n$

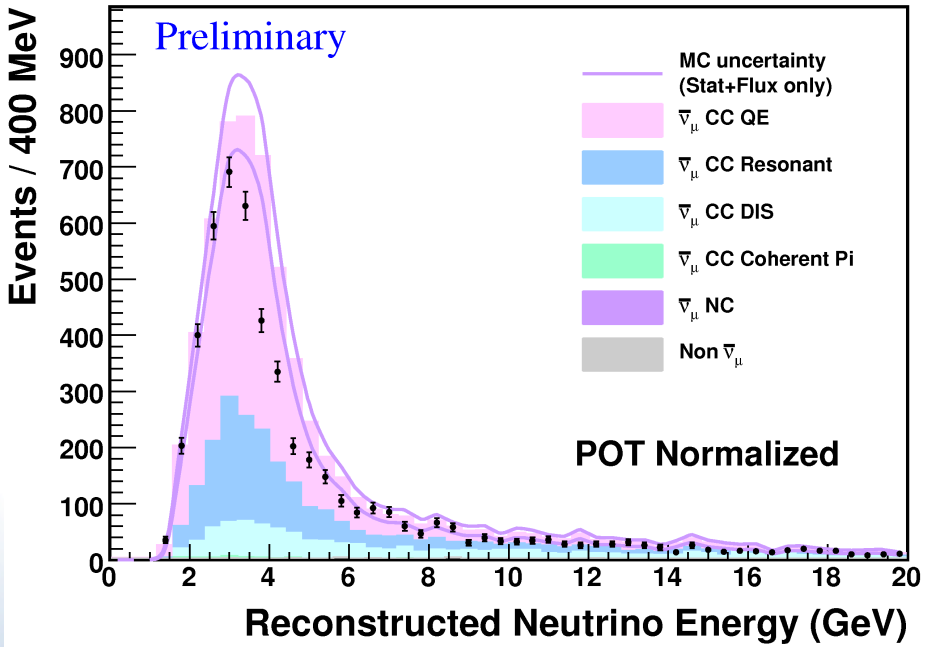


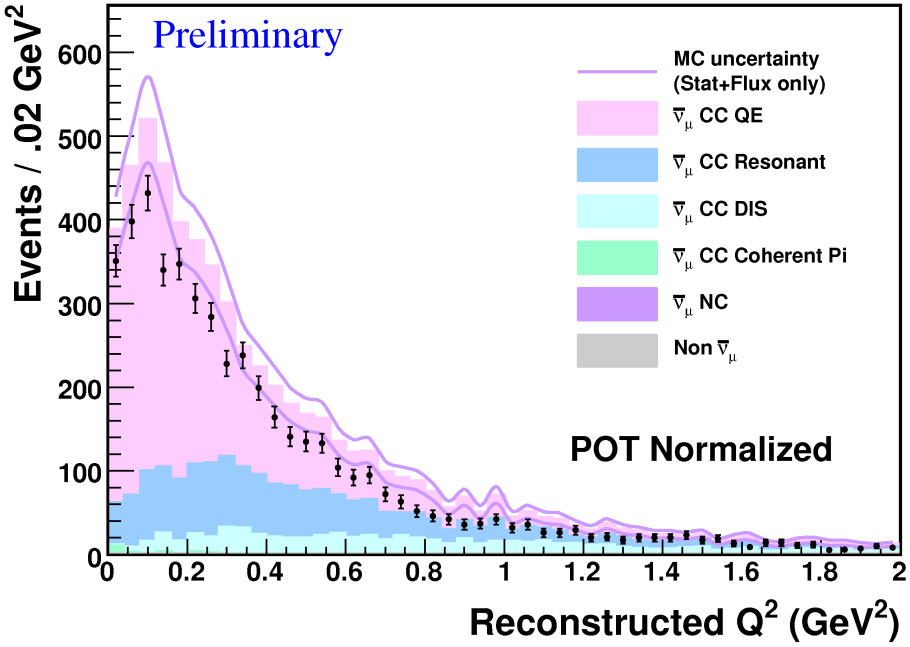
$$E_\nu = 0.5(m_N^2 - m_P^2 - m_\mu^2 + 2m_P E_\mu)(m_P - E_\mu + p_\mu \cos\theta_\mu)^{-1}$$
$$Q^2 = 2E_\nu(E_\mu - p_\mu \cos\theta_\mu) - m_\mu^2$$



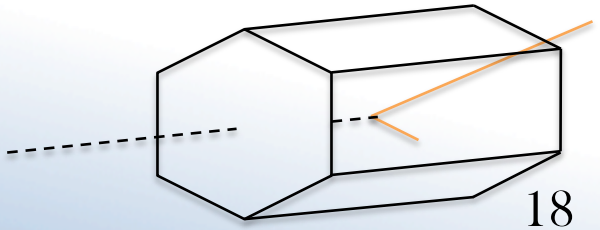
Anti-Neutrino Candidate Distributions

0.4E20 POT, partial detector – *half of partial data set*



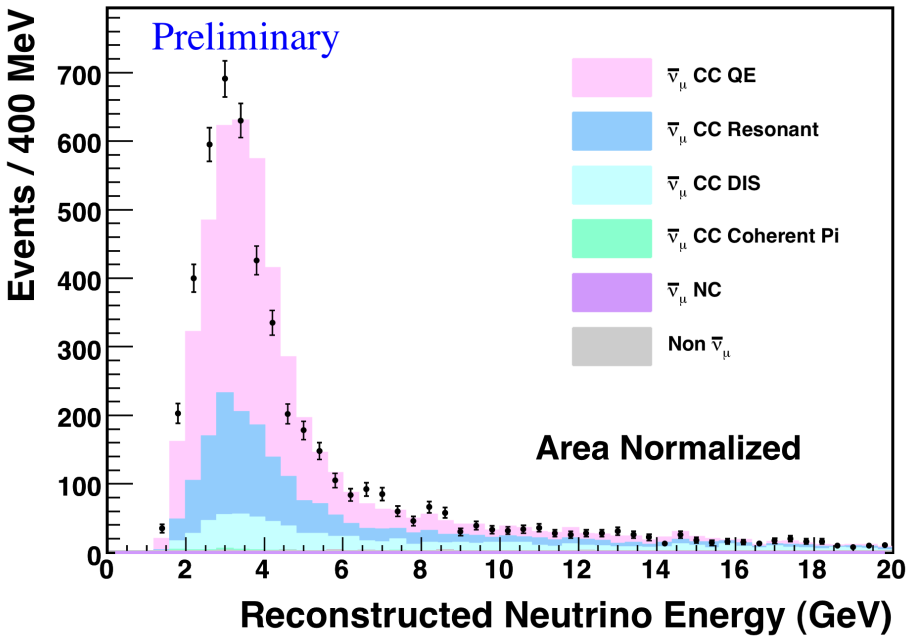


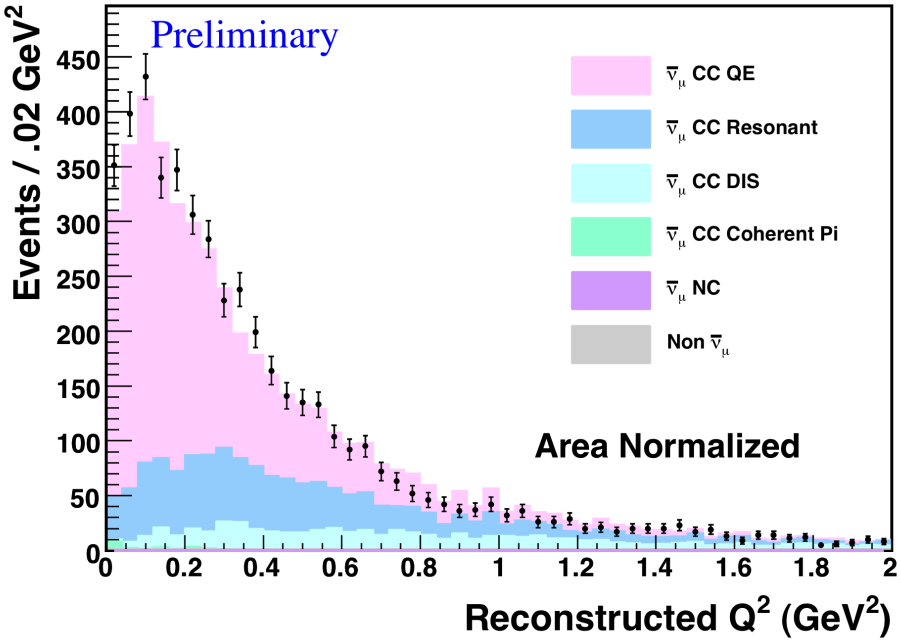
- Absolute predictions from flux simulation, GENIE 2.6.2, MINERvA simulation
- Event deficit is flat in Q^2 and not flat in E_ν

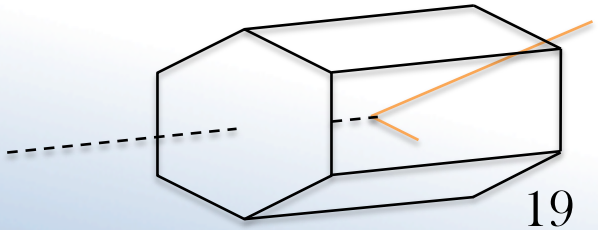


Anti-Neutrino Candidate Distributions

0.4E20 POT, partial detector



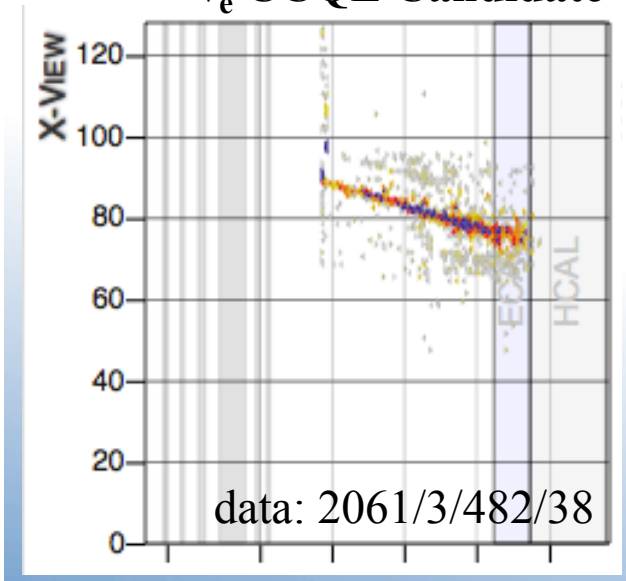




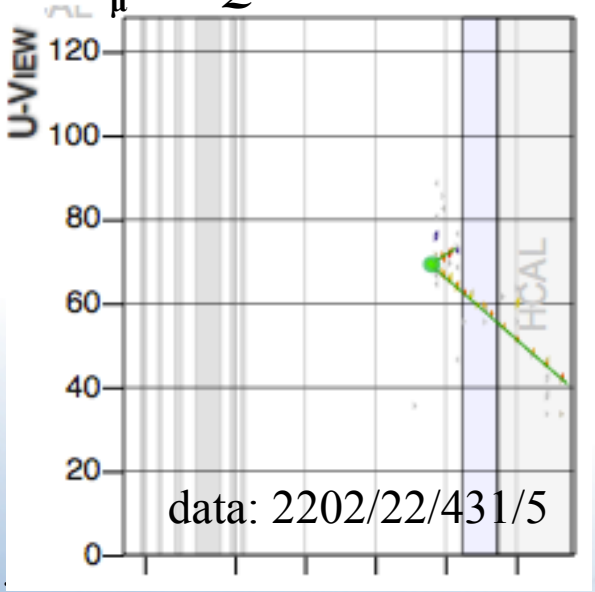
Other CC Elastic Scattering

- There are a wealth of charged current elastic scattering studies that can be done with MINERvA:
  - anti-neutrino, lone track, track + recoil
  - neutrino, one/two track
  - meson exchange currents / 2p2h signatures
  - electron neutrino elastic scattering

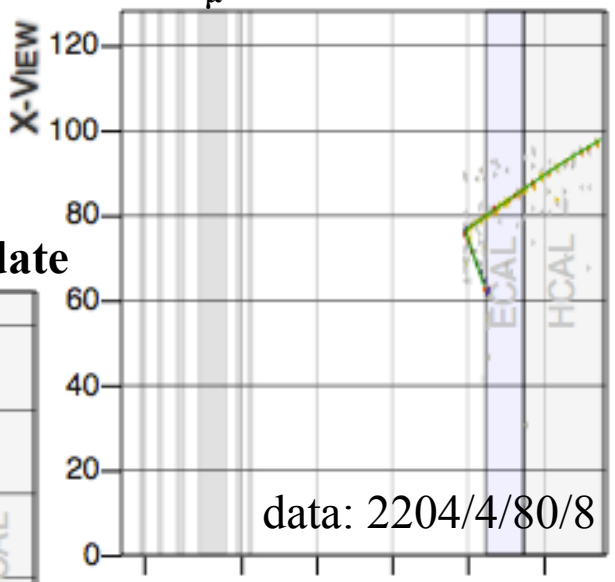
ν_e CCQE Candidate

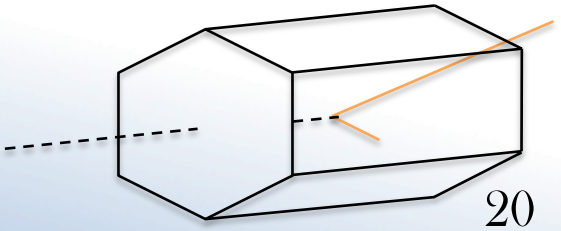


ν_μ '*CCQE-like*' Candidate



ν_μ CCQE Candidate



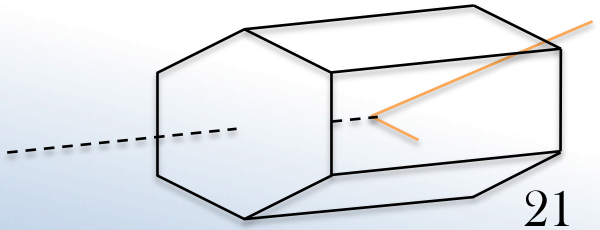


Neutral Current Elastic Scattering

- MINERvA will can also shed light on neutral current elastic scattering; the detector allows for exclusive measurements.

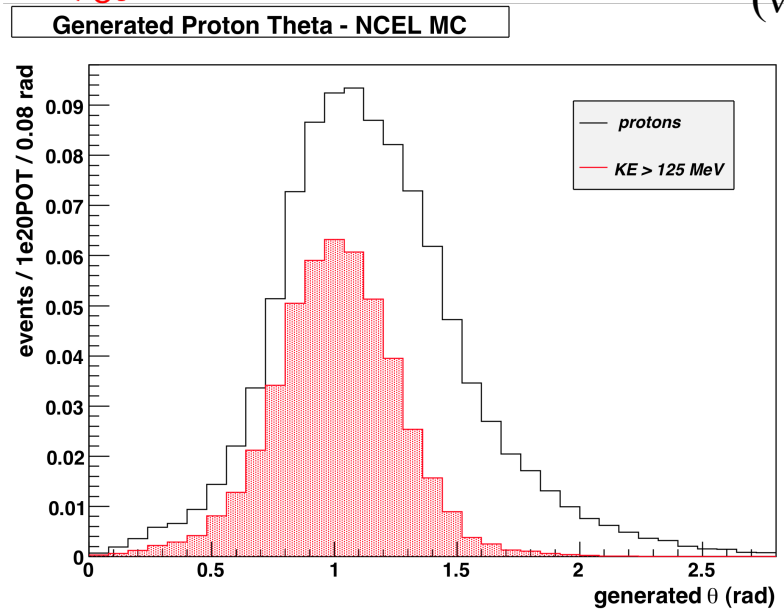
- Neutral current elastic analyses are typically more difficult than the corresponding CC ones:
  - particle identification difficult for low energy signals
  - background rejection becomes more important

- Neutral current elastic scattering analyses yields different, but interesting, physics insights than corresponding CC ones.
  - strange axial form factor - Δs
  - background for oscillation experiments



Neutral Current Elastic Scattering

(νp final state)



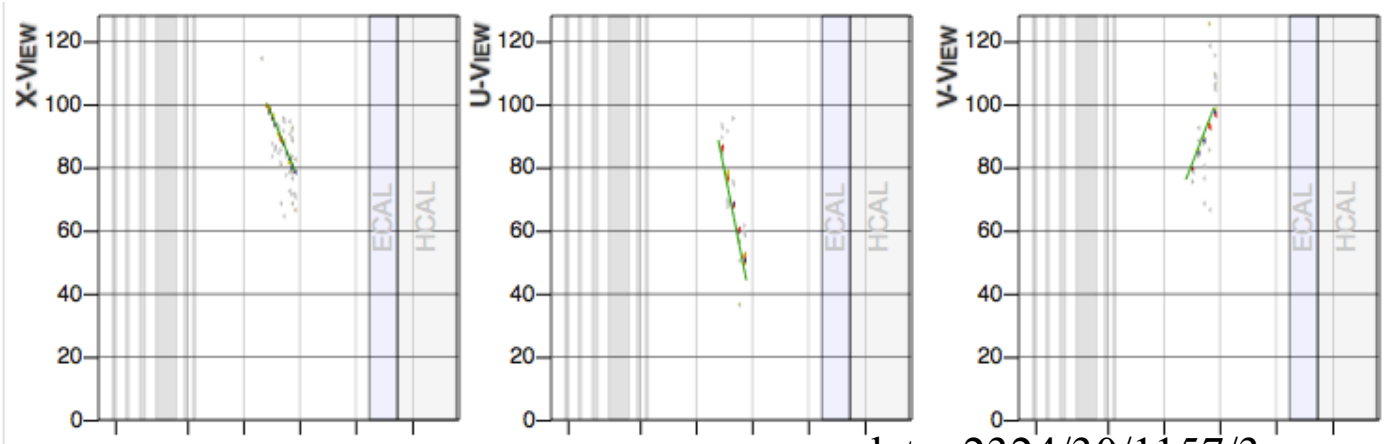
- The NC elastic signal is a heavy ionizing, potentially high-angle, lone track; this provides interesting challenges to reconstruction.

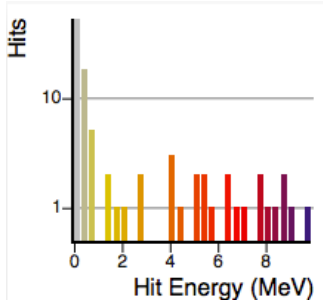
Proton KE/P Conversions:

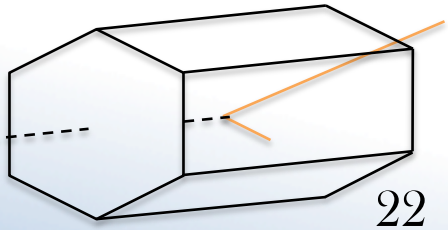
125 MeV KE ≈ 500 MeV Mom.
150 MeV KE ≈ 550 MeV Mom.
200 MeV KE ≈ 650 MeV Mom.

Approx. Proton KE/Ranges:

80 MeV ≈ 5.2 g/cm^2
125 MeV ≈ 11.5 g/cm^2
250 MeV ≈ 38 g/cm^2







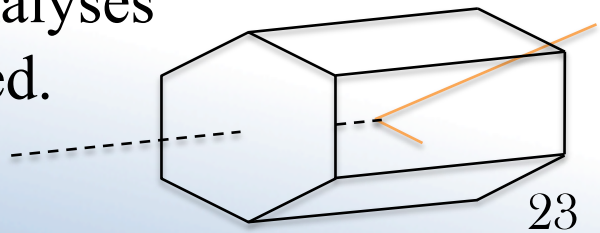
data: 2324/30/1157/3

Conclusions

- Neutrino elastic scattering has been and will continue to be an important interaction channel and thus needs to be thoroughly understood.

- MINERνA is in a position to provide the physics community with precision elastic scattering results to assist future experimental and theoretical studies.
  - anti-ν elastic kinematic distributions (NOW)
  - anti-ν elastic differential cross sections (FUTURE)
  - ν elastic kinematics distributions and differential cross sections (FUTURE)
  - ν neutral current elastic distributions (FUTURE…)

- There are many other interesting physics analyses possible with the varying data sets; stay tuned.

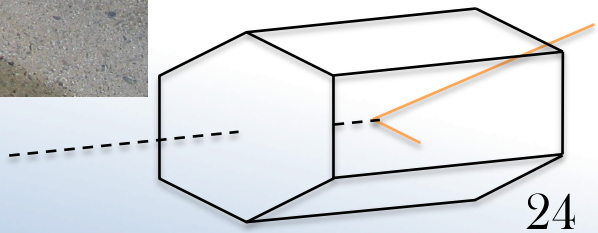


Many thanks to….

… the audience

… UCI and MINERvA

… the conference and session conveners



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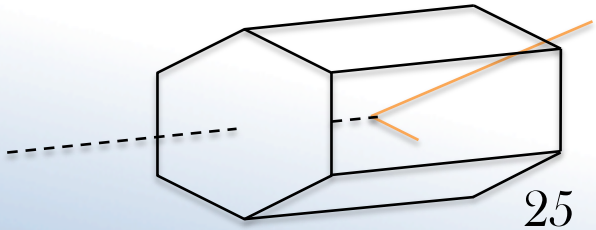
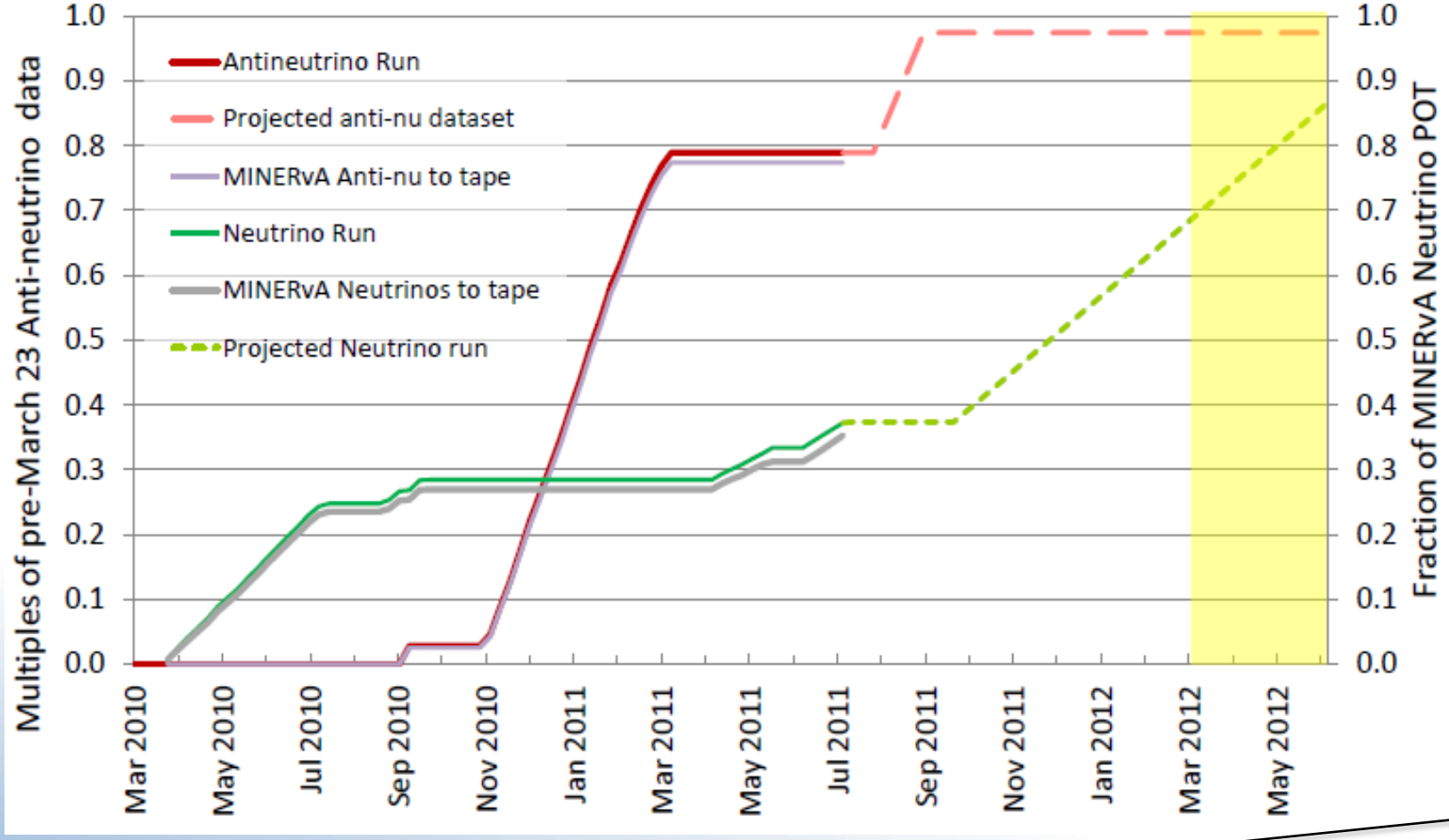
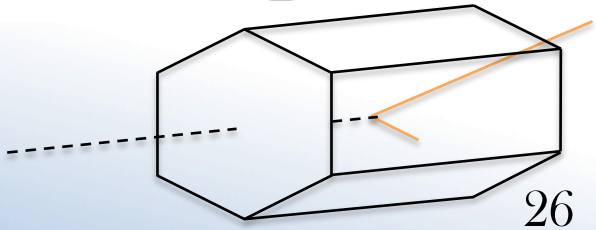


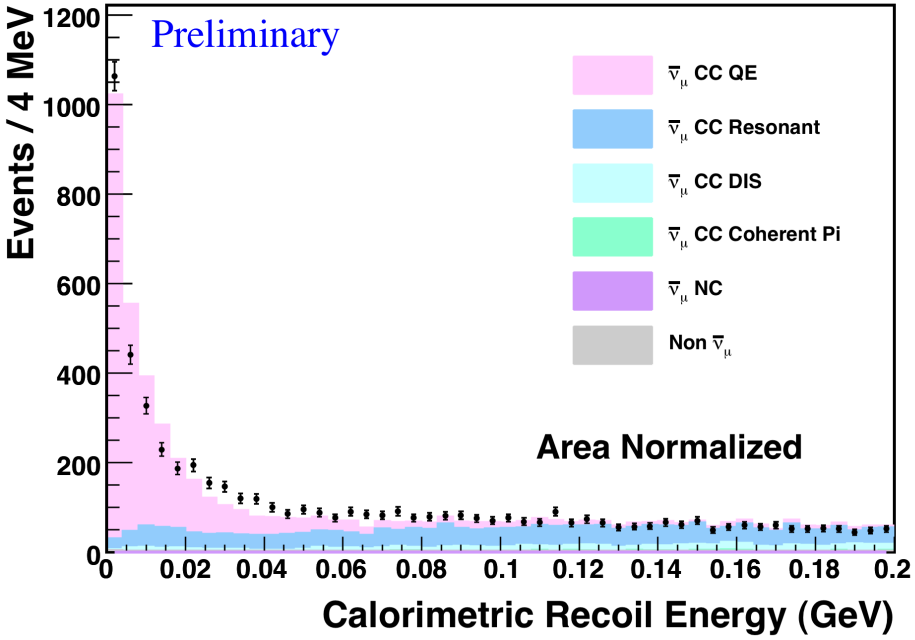
Potential MINERvA Schedule



Full scale: neutrino 4.9e20POT, anti-neutrino 1.76e20POT

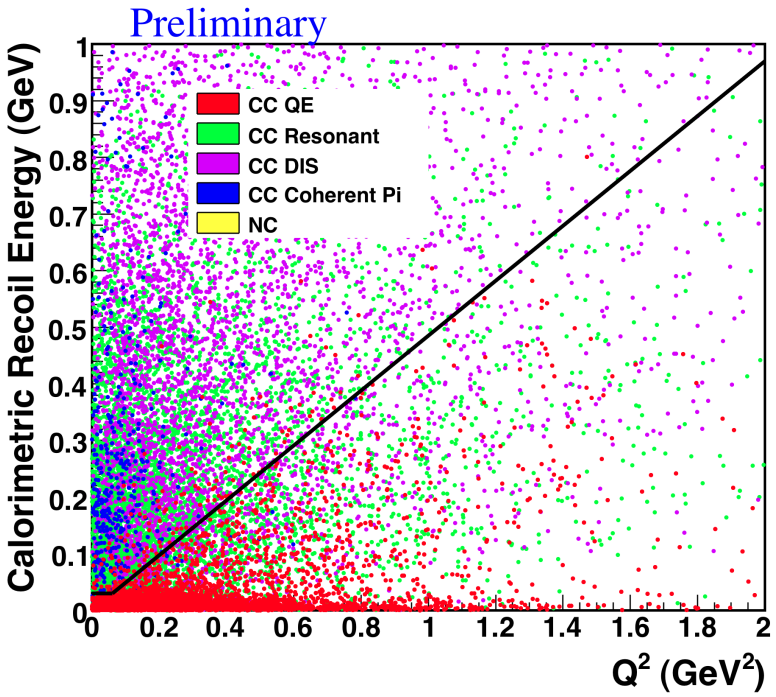


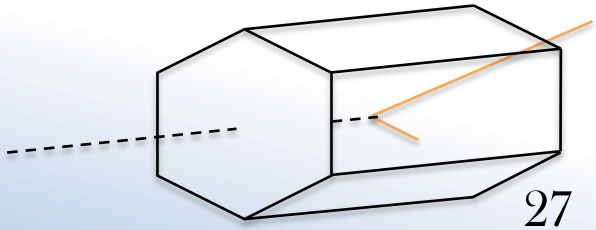
Anti-Neutrino Elastic Scattering



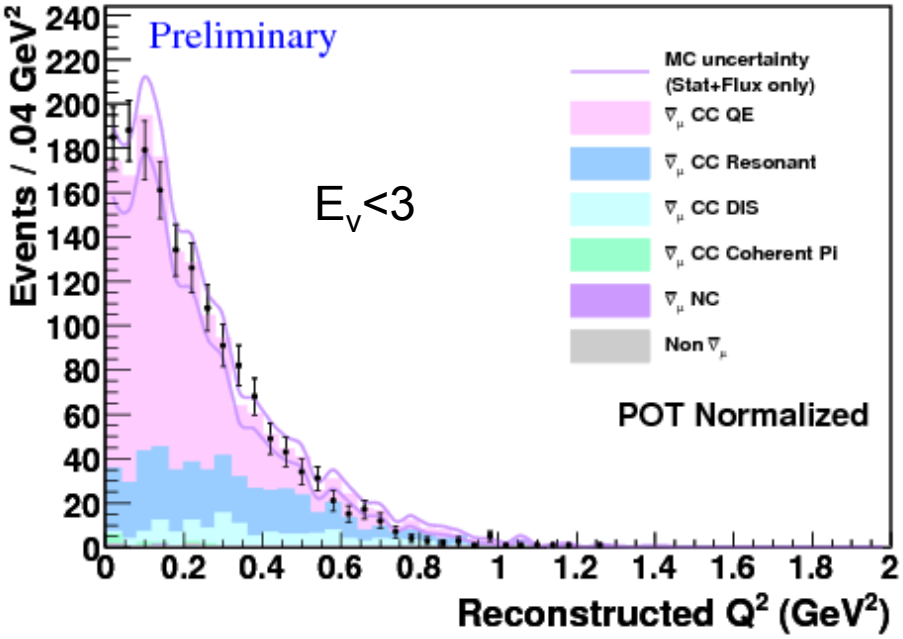
Above: data/MC overlay of recoil energy when other anti-ν CCQE cuts are applied

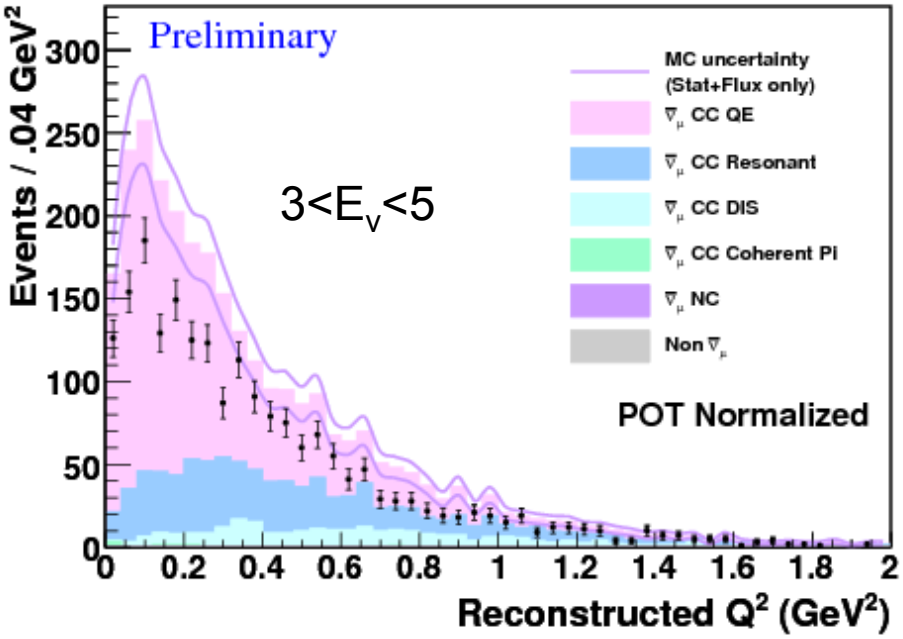
Below: 2D plot of recoil vs. Q^2 for various MC event channels



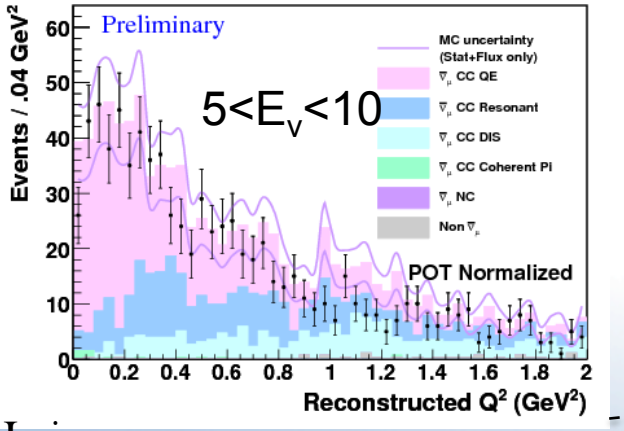


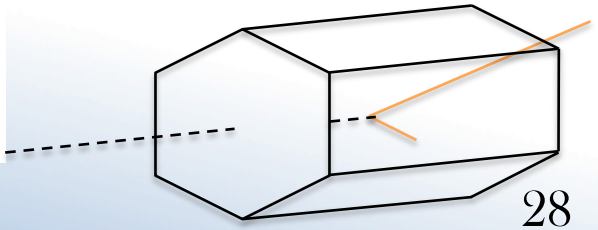
Anti-Neutrino Distributions



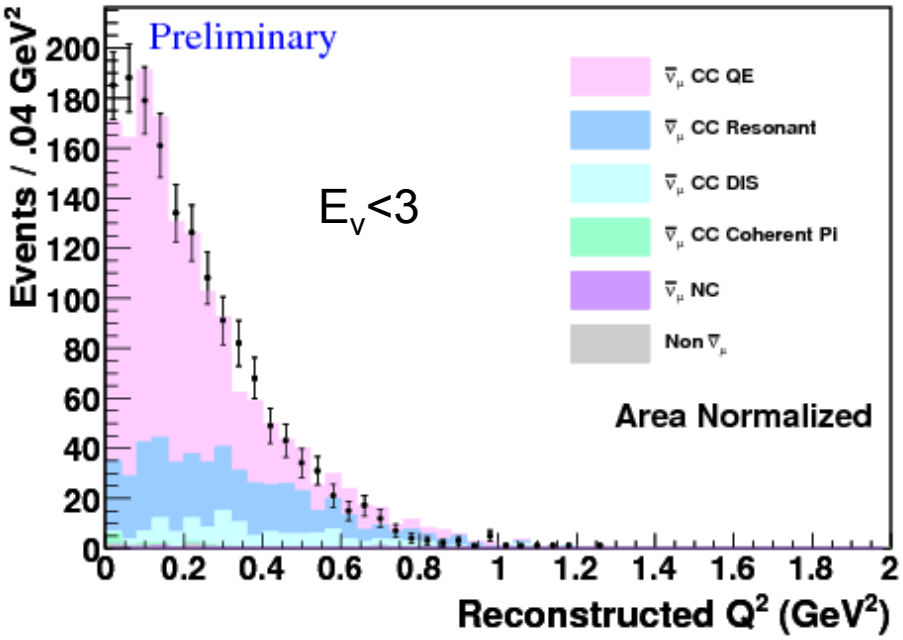


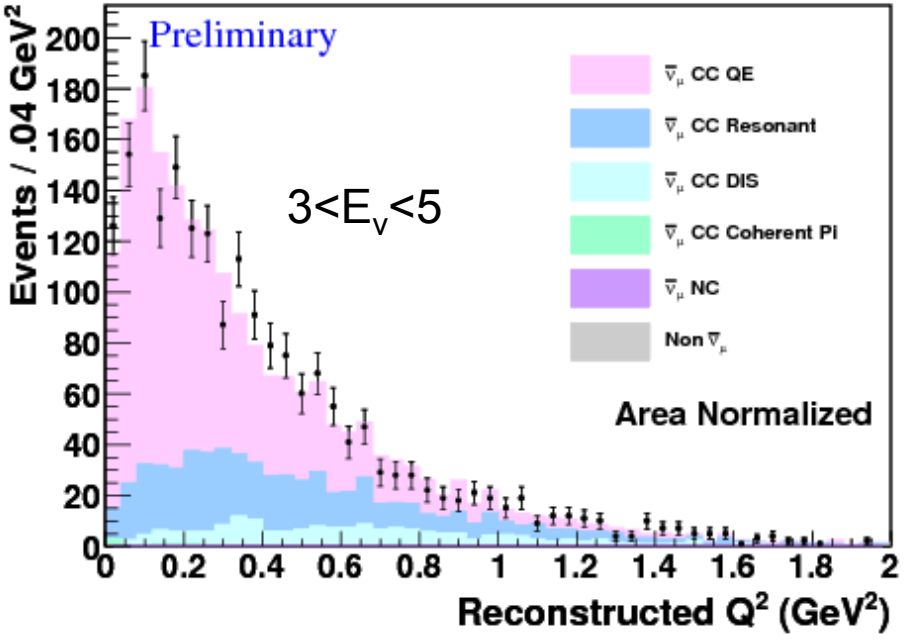
Caption: event Q^2 for various energy ranges





Anti-Neutrino Distributions





Caption: event Q^2 for various energy ranges